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Fluid Interfaces of Triangular Containers in Reduced Gravity Environments

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Purdue University, West Lafayette, Indiana 2001

Introduction

•Purdue University offers a design, build, and test class in corporation with the NASA Reduced Gravity Student Flight Opportunity Program (RGSFOP) for junior and senior students in aerospace engineering, along with a freshman honors team

•Team-oriented project from beginning to end, supervised by Professor Steven H. Collicott

•The Purdue Freshman Honors team consisted of six students majoring in aerospace, mechanical engineering and biology

•The Spring 2001 Honors team obtained a copy of M. M. Weislogel's 2001 AIAA paper "Capillary Flow in Cylindrical Containers of Irregular Polygonal Section" describing a theory to model fluid behavior along angles in micro-gravity (μG) as an idea for a KC-135 proposal, because longer testing periods are needed to prove the theory

•Collaborating with Weislogel, the team proposed our own experiment to validate or deny the theory's statement in regards to a stationary point existing on the interface of the meniscus

•To our knowledge, this concept has never been tested outside of NASA Glenn's Drop Tower Facility. Therefore, it is a new experiment with a variety of opportunities to build upon for future research ranging from space propulsion to biological applications

Method

•Objective: To examine capillary dominated fluid dynamics in a μG environment, specifically the bottom portion of the meniscus in the triangular tank geometries during a flight on the KC-135

•Experiment designed for viewing seven angles of hand built clear acrylic tanks with two different viscosities of silicon oil

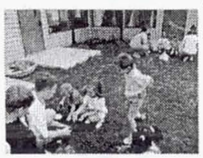
	Day 1 2cs silicon oil	Day 2 5cs silicon oil
1st set of parabolas	45°, 60°, 90°	45°, 60°, 90°
2nd set of parabolas	30°, 60°, 120°	30°, 60°, 120°
3rd set of parabolas	75°, 60°, 105°	75°, 60°, 105°

•Angle selection based on 2.2 second drop tower test results for data comparison of approximately 20 second μG parabolas

•60°-60°-60° tank used as a control for reference to effects of g-jitter, defined as the random vibrations of the experiment with respect to the plane

•Project constraints include mounting experimental frame to the KC-135, double containment of liquids, plane g-jitter, time limitations, etc.

•Data gathering by two digital video cameras and one digital still camera placed perpendicular to viewing surface with an EL backlighting sheet for greater contrast, after flight dates data is digitized, passed through NASA's mini-tracker software, and compared to the proposed theory for analysis



•Complete outreach activities with the community to expand the public's awareness of space exploration and research opportunities including spin-offs

•Activities: film canister rockets, edible space stations, presentations

•Hometown area schools & local newspaper articles, television recognition, and Purdue publications

•Team continues to provide outreach on as needed basis

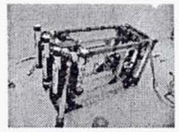
Acknowledgements: NASA RGSFOP for the flight and opportunity
Purdue University – School of Aeronautical & Astronautical Engineering,
Dean of Engineering, Dr. Collicott, and team members

Building & Experimentation

•Flight Preparations (at Purdue University, West Lafayette, IN)

•Upon proposal acceptance, test experimental data package submitted to clarify technicalities

•Team members worked in a unique hands-on environment - building our experiment with minor assistance from machinists



•Each tank took approximately 30 hours, starting as a block of acylic and finishing as a finely polished 18 inch long experimental tank.

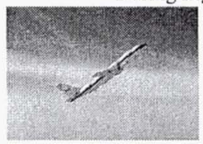
•Before shipment, the experiment was fully constructed to calibrate camera placement, practice tank exchange procedures, and verify items needing attention for flight assembly.

•During the Program (at NASA Johnson Space Center [JSC], Houston,TX)

•Upon arrival at JSC, the team assembled our experiment for the Test Readiness Review and upcoming flight days; participants completed hypoxia training, attended lectures, and took tours of JSC.

•Due to poor weather, our flights were postponed, providing for extra practice of camera mounting and tank exchange with our experiment while bolted downinside the KC-135.

•During flight, as designed, minimal interaction is needed by flight crew members



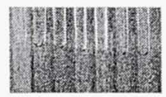
•Cameras are powered on and set to record

•Two tanks are exchanged in between parabola sets

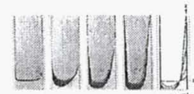
•(after approx. 10 μG parabolas)

•Student fliers observe data collection and enjoy the 'out-of-this-world' experience as a year-long effort reward

Results & Conclusions



•Acquired more than 223 still high-resolution images and 4 hours of total video of the fluid interface in μG



•Sequence of images of our 60° control's meniscus (above) compared to Weislogel's drop tower results (on right)

•Variety of operational oversight issues:

•Some captured data not useable due to low quality, excess noise in data due to high KC-135 illumination and cameras trying to adjust for it

•Imaging system mounts not as rigid as designed, causing wobbles in data collection during transitions in flight and turbulence

•Data analysis requires several procedures and due to the large amount of data collected, complete analysis is not completed and preliminary results are inferred: G-jitter affected fluid flow displaying an acceleration occurring on the the fluid

•Future experiment suggestions

1) Re-test as a KC-135 free-floating experiment, option not available during flight dates
2) During a parabola set, use the same angle in all tanks and compare results

•If the theory is proven true, it will lead to more accurate models of fluid wicking in reduced gravity aiding in designing better propellant management devices and understanding fluid motion in biological and material manufacturing experiments

•Special note: all four Honors flight members did not live up to the plane's nickname, "The Vomit Comet"

World Space Congress 2002

To Whom It May Concern:

The following is the submitted abstract from Purdue University's 2001 Freshman Honors Team final report, "Fluid Interfaces of Triangular Containers in Reduced Gravity Environments," after completing NASA's Reduced Gravity Student Flight Opportunities Program (RGSFOP). I have submitted the attached poster draft for entry into the 2002 World Space Congress Poster Session. Purdue University will be paying for all fees regarding the entry (registration, production, etc). However, I was informed I may need to fill out a From 548 to receive a blanket release, I hope the information provided will do for the required documentation. If more information is needed, please contact me and I will try to submit it on a timely fashion.

Thank you,

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Experimental abstract

Capillary dominated fluid dynamics will be examined in a reduced-gravity environment onboard the KC-135; in particular, the behavior of the lower portion of the meniscus in triangular tank geometries. Seven clear acrylic tanks were constructed to view seven angles of the four geometries. Silicon oil with two different viscosities, 2cs and 5cs silicon oil, were used on different days of the flight.

Six tanks and one control tank are filled with a certain viscosity fluid for each flight day. During each parabola, three tanks are tested at time. The experimental tanks are exchanged between parabola sets on the KC-135. The 60°-60°-60° control tank is viewed throughout the flight. To gather data, two digital video cameras and one digital still camera are placed perpendicular the viewing surface. To provide a greater contrast in the meniscus, an EL backlighting sheet was used to backlight the tanks. These images and video are then digitized, passed through NASA's mini-tracker software, and compared to a theory published my M. M. Weislogel, "Fluid Interface Phenomena in a Low-Gravity Environment: Recent Results from Drop Tower Experimentation."

By focusing on a lower portion of the meniscus and using longer periods of reduced gravity, this experiment may confirm that a stationary point exists on the fluid surface. This information will enable better designing of propellant management devices, especially satellite propellant refilling and gas venting. Also, biological and material processing systems in reduced gravity environments will benefit from this data.